Claims

[c1] 1. A target locating and tracking system usable with a radiation therapy delivery source that delivers radiation to a target in a body, the radiation being delivered to a predetermined volume configured around a machine isocenter spaced apart from the radiation delivery source, comprising:
a marker fixable at a position relative to the target in the body, the marker being excitable by an external excitation source to produce an identifiable marker signal from the marker while in the body;
sensors spaced apart from each other in a known geometry relative to each other and positioned to identify the marker signal from the marker, the sensors being configured to measure the marker signal and to provide marker measurement signals;
a reference device positionable at a selected position relative to the radiation therapy delivery source and the machine isocenter, the reference device configured to produce a reference signal measurable by a plurality of the sensors; and
a data processing unit coupled to the sensors to receive the marker measurement signals, the data processing unit being configured to use the marker measurement signals to determine the location of the target volume with a target isocenter and the location of the reference device relative to the plurality of sensors, and the data processing unit being configured to identify the location of the target isocenter relative to the machine isocenter.

[c2] 2. The target locating and tracking system of claim 1, further comprising a plurality of markers implantable in the body, each marker being excitable by the excitation source to produce a unique marker signal measurable by the plurality of sensors.

[c3] 3. The target locating and tracking system of claim 2 wherein the plurality of markers includes at least three markers.

[c4] 4. The target locating and tracking system of claim 3 wherein the markers are each axially misaligned with each other.

[c5] 5. The target locating and tracking system of claim 2 wherein the marker signal

from each marker has a unique frequency different from the frequency of other marker signals.

[c6] 6. The target locating and tracking system of claim 1 wherein the marker is a wireless marker implantable in the body.

[c7] 7. The target locating and tracking system of claim 6 wherein the data processing unit is configured to determine the position of the target isocenter relative to the sensors.

[c8] 8. The target locating and tracking system of claim 1 wherein the marker is permanently implantable in the body.

[c9] 9. The target locating and tracking system of claim 1 wherein the marker is a single-axis, resonating marker.

[c10] 10. The target locating and tracking system of claim 1 wherein the marker is a wireless marker.

[c11] 11. The target locating and tracking system of claim 1 wherein the reference device is measurable by a plurality of sensors.

[c12] 12. The target locating and tracking system of claim 1 wherein the data processing unit is configured to determine the location of the machine isocenter relative to the plurality of sensors and relative to the treatment target isocenter based upon the signal of the linear accelerator reference.

[c13] 13. The target locating and tracking system of claim 1 , further comprising an excitation source remote from the marker and configured to generate an excitation field that energizes the marker.

[c14] 14. The target locating and tracking system of claim 1 wherein the plurality of sensors are fixed to a base in the known geometry to form a sensor array.

[c15] 15. The target locating and tracking system of claim 1 , further comprising a patient support structure shaped and sized to support the body, the plurality of sensors is mounted to the patient support structure.

[c16] 16. The target locating and tracking system of claim 15 wherein the table structure has a base and a tabletop, the base being in a fixed location relative to the sensors and the tabletop being movably adjustable relative to the sensors.

[c17] 17. The target locating and tracking system of claim 1 , further comprising a monitoring system coupled to the data processing unit, the monitoring system having a feedback portion configured to provide feedback information about the position of the target isocenter and the machine isocenter relative to each other.

[c18] 18. The target locating and tracking system of claim 17 wherein the feedback portion is a visual display.

[c19] 19. The target locating and tracking system of claim 17 wherein the data processing unit and monitoring system are configured to identify and display movement in real time of the target and machine isocenters relative to each other.

[c20] 20. The target locating and tracking system of claim 1 wherein the marker is one of a plurality of markers axially misaligned with each other, and the data processing unit is configured to identify a three-dimensional spatial position and orientation of the target relative to the plurality of sensors and the machine isocenter.

[c21] 21. The target locating and tracking system of claim 1 wherein the reference device is at least one excitable marker mountable to the radiation therapy delivery source.

[c22] 22. The target locating and tracking system of claim 1 wherein the reference device is out of physical connection with the plurality of sensors and the data processing unit to provide a wireless interconnection therebetween.

[c23] 23. A target locating and monitoring system usable with a radiation therapy delivery source that delivers radiation to a target in a body, the radiation being delivered to a treatment volume determined by a machine isocenter spaced apart from the radiation therapy delivery source, comprising:
a plurality of markers fixable on or in the body at a known geometry relative to

each other and relative to the target, the markers each being excitable by an external excitation source to produce an identifiable marker signal from the marker while in the body;

sensors spaced apart from each other and positioned to measure the marker signals from the markerseach sensor being configured to provide marker measurement signals for one or more of the markers;

a reference device positionable at a selected position relative to the radiation delivery source and the machine isocenter; and

a data processing unit coupled to the sensors to receive the marker measurement signals from the sensors, the data processing unit being configured to use the marker measurement signals to determine the location of the target volume having a target isocenter relative to the plurality of sensors, and the data processing unit being configured to identify the location of the target isocenter relative to the machine isocenter.

[c24] 24. The target locating and monitoring system of claim 23 wherein the signal from each marker has a measurable signal, and each sensor measures the signal from at least one of the markers, the computer controller being configured to determine the location and/or spatial orientation of the target within the body based upon measurable signals.

[c25] 25. The target locating and monitoring system of claim 23 , further comprising an excitation source remote from the markers and configured to operate an excitation field that energizes the markers.

[c26] 26. The target locating and monitoring system of claim 23 wherein the plurality of sensors are fixed to a base to define a sensor array positionable as a unit at a selected position remote from the markers.

[c27] 27. The target locating and monitoring system of claim 23 , further comprising a patient support structure shaped and sized to support the body, the plurality of sensors being in a fixed position relative to a portion of the patient support structure.

[c28] 28. The target locating and monitoring system of claim 27 wherein the patient

support structure has a base and a tabletop.

[c29] 29. The target locating and monitoring system of claim 23 , further comprising a monitoring system coupled to the computer controller, the monitoring system having a feedback portion configured to provide feedback information about the position of the target isocenter and the machine isocenter relative to each other.

[c30] 30. The target locating and monitoring system of claim 29 wherein the feedback portion is a visual display.

[c31] 31. The target locating and monitoring system of claim 29 wherein the computer controller and monitoring system are configured to identify and display movement in real time of the target and machine isocenters relative to each other.

[c32] 32. The target locating and monitoring system of claim 23 wherein the plurality of markers includes at least three markers.

[c33] 33. The target locating and monitoring system of claim 23 wherein the plurality of markers are axially misaligned with each other.

[c34] 34. A radiation therapy delivery system usable to irradiate a selected target within a body, comprising:
a radiation delivery assembly that delivers radiation from a radiation therapy delivery source to a machine isocenter spaced apart from the radiation delivery source;
a marker fixable in or on the body at a position relative to the target, the being excitable by an external source to produce a measurable marker signal while in the body;
a plurality of sensors spaced apart from each other and positioned in a known geometry relative to each other, the sensors being configured to measure the marker signals and generate marker measurement signals;
a reference device coupled to the radiation therapy delivery source and positioned remote from the machine isocenter; and
a data processing unit coupled to the sensors to receive the marker measurement signals, the data processing unit being configured to use the

marker measurement signals to determine the location of the target volume having a target isocenter and the location of the reference device relative to the plurality of sensors, and the data processing unit being configured to identify the location of the target isocenter relative to the machine isocenter.

[c35] 35. The radiation delivery system of claim 34 , further comprising a plurality of markers implantable in the body, each marker being excitable by the external source to produce a marker signal measurable by the plurality of sensors.

[c36] 36. The radiation delivery system of claim 35 wherein the marker signal from each marker is a unique signal different from the other marker signals.

[c37] 37. The radiation delivery system of claim 35 wherein each marker signal has a frequency different from the frequencies of other marker signals.

[c38] 38. The radiation delivery system of claim 35 wherein the marker signal has a signal strength, and the data processing unit calculates the spatial location of the markers and target isocenter based upon the marker signals.

[c39] 39. The radiation delivery system of claim 34 wherein the reference device is mounted on the radiation delivery assembly and provides a reference signal measurable by the sensors.

[c40] 40. The radiation delivery system of claim 34 wherein the reference device provides a signal measurable by the plurality of sensors, the data processing unit is coupleable to the linear accelerator reference device and the data processing unit is configured to identify the location of the machine isocenter relative to the plurality of sensors based upon the measurements of the reference signal.

[c41] 41. The radiation delivery system of claim 34 , further comprising an excitation source positionable exterior of the body and configured to excite the marker to produce the marker signal.

[c42] 42. The radiation delivery system of claim 34 wherein the plurality of sensors defines a sensor array positionable as a unit relative to the marker.

[c43] 43. The radiation delivery system of claim 34 further comprising a patient support structure shaped and sized to support the body in which the marker is implanted, and the sensors are mounted in a fixed location relative to a portion of the patient structure.

[c44] 44. The radiation delivery system of claim 34 wherein the patient support structure has a base and a tabletop movably adjustable relative to the sensors for positioning the target isocenter co-incident with the machine isocenter.

[c45] 45. The radiation delivery system of claim 34 , further comprising a monitoring system having a feedback portion coupled to the data processing unit and configured to provide feedback information about the position of the machine isocenter and the target isocenter relative to each other.

[c46] 46. The radiation delivery system of claim 34 wherein the marker is one of a plurality of markers, the markers each being axially misaligned with each other, and the computer controller being configured to calculate a three-dimensional spatial position and orientation of the target relative to the plurality of sensors.

[c47] 47. The radiation delivery system of claim 34 wherein the radiation therapy delivery source includes a movable gantry, and the reference device is mounted on the gantry at a position spaced apart from the plurality of sensors.

[c48] 48. The radiation delivery system of claim 34 wherein the reference device is a wireless excitable marker mounted to the radiation therapy delivery source.

[c49] 49. The radiation delivery system of claim 34 wherein the radiation therapy delivery assembly is one of an intensity modulated radiation therapy (IMRT) system, a three-dimensional conformal external beam radiation system, a stereotactic radiosurgery system, tomo therapy and a brachytherapy system.

[c50] 50. The radiation delivery system of claim 34 wherein the data processing unit contains visual diagnostic data identifying the location of the marker and the location and orientation of the target, the data processing unit being configured to compare the visual diagnostic data to the location and spatial orientation of the target within the body relative to the plurality of sensors and to identify a

target isocenter within the target prior to application of radiation treatment to the target.

[c51] 51. A radiation treatment system usable to deliver ionizing radiation to a selected target within a body, comprising:
a movable gantry configurable to deliver the ionizing radiation at a treatment isocenter remote from the gantry;
a marker fixable at a position relative to the target within the body, the marker being excitable by an external source to produce a measurable marker signal while in the body;
sensors spaced apart in a known geometry relative to each other and positioned to measure the marker signal, each sensor being configured to measure the marker signal and provide a marker measurement signal;
a linear accelerator reference device mounted on the gantry at a known position relative to the machine isocenter; and
a computer controller coupled to the sensors to receive the marker measurement signals and configured to use the marker measurement signals to determine the location of the target volume and a target isocenter in the target volume relative to the sensors, and the computer controller being coupled to the reference device and configured to identify the location of the target isocenter relative to the machine isocenter.

[c52] 52. The radiation treatment system of claim 51, further comprising a patient support structure shaped and sized to support the body in which the marker is implanted, and the sensors are mounted in a fixed location relative to a portion of the patient support structure.

[c53] 53. The radiation treatment system of claim 51, further comprising a monitoring system coupled to the computer controller, the monitoring system having a feedback portion configured to provide feedback information about the position of the machine isocenter and the target isocenter relative to each other.

[c54] 54. The radiation treatment system of claim 43 wherein the computer controller and monitoring system are configured to identify and display real time movement of the target and machine isocenters relative to each other.

[c55] 55. The radiation treatment system of claim 53 , wherein the computer controller contains imaging data identifying the location of the marker and the location and orientation of the target, the computer controller being configured to compare the imaging data to the location and spatial orientation of the target within the body relative to the plurality of sensors and to identify a target isocenter within the target prior to application of radiation treatment to the target.

[c56] 56. A radiation target alignment system usable with a radiation delivery source that delivers selected doses of radiation to a selected target in a body, comprising:

an imaging system configured to obtain image data of the target and at least one marker positioned within the body, and to define a simulated target model having a spatial relationship and orientation within the body using the image data;

a marker implantable in or on the body at a selected position relative to the target, the marker being excitable by an external source to produce a measurable signal while in the body;

a plurality of sensors spaced apart in a known geometry relative to each other and positioned to identify the signal from the marker in the body, each sensor being configured to measure the marker signal and provide a marker measurement signal;

a data processing unit coupled to the sensors to receive the marker measurement signal for the marker, the data processing unit being configured to use the marker measurement signal and the image data to determine an actual target model of the target's actual location within the body relative to the plurality of sensors, and to identify a target isocenter within the target, the data processing unit being configured to compare and align the actual target model and the simulated target model in preparation for radiation treatment of the target.

[c57] 57. The radiation target alignment system of claim 56 wherein in the marker is one of a plurality of markers attachable to the body, and each marker generates a unique measurable signal different from the other marker signals.

[c58] 58. The radiation target alignment system of claim 57 wherein the plurality of markers includes at least three markers.

[c59] 59. The radiation target alignment system of claim 57 wherein the plurality of markers are axially misaligned with each other.

[c60] 60. The target locating and tracking system of claim 56 wherein the marker is one of a plurality of markers, and the markers each being axially misaligned with each other, the data processing unit being configured to identify a three-dimensional spatial position as well as orientation of the target relative to the plurality of sensors.

[c61] 61. The radiation target alignment system of claim 56 with the radiation delivery source adapted to deliver radiation to a machine isocenter spaced apart from the radiation delivery source, wherein the data processing unit is configured to identify the location of the machine isocenter relative to the actual target isocenter.

[c62] 62. The radiation target alignment system of claim 56 , further comprising a monitoring system coupled to the data processing unit, the monitoring system having a display portion configured to display the position of the machine isocenter and the actual target isocenter relative to each other.

[c63] 63. The radiation target alignment system of claim 62 wherein the data processing unit and monitoring system are configured to identify and display real time movement of the target and machine isocenters relative to each other.

[c64] 64. An adjustable patient support assembly for use with a radiation delivery system that delivers radiation to a selected target in a body, the radiation being delivered to a machine isocenter spaced apart from the radiation delivery source, comprising:

a base;

a support structure attached to the base;

sensors spaced apart from each other in a known geometry relative to each other and coupled to the base, the sensors being positioned to measure a signal from an excitable marker implantable in the body at a selected position relative

to the target, each sensor being configured to provide signal measurement data;

a data processing unit coupled to the sensors to receive the signal measurement data for the marker, the data processing unit being configured to use the signal measurement data for the marker to determine the location of the target and a target isocenter in the target relative to the sensors, the data processing unit being configured to identify the location of the target isocenter relative to the machine isocenter; and

a movement control device connected to the support structure to selectively move the support structure relative to the base and the sensors, the movement control device coupled to the data processing unit and being movable in response to the information from the data processing unit to position the target isocenter co-incident with the machine isocenter.

[c65]

65. A method of identifying and tracking a selected target in a body for application of radiation to the target from a radiation delivery source, comprising:

determining a general location of the target in the body;

implanting a marker in the body at a selected position relative to the target, the marker being excitable by an external excitation source to produce an identifiable marker signal while in the body;

exciting the implanted marker with the external excitation source to produce the identifiable marker signal;

measuring the marker signal from the implanted marker with sensors exterior of the body, the sensors being positioned at a known geometry relative to each other;

determining a target isocenter in the target within the body based upon the measurements from the sensors of the marker signal;

determining a position of a reference device relative to the plurality of sensors, the reference device being located at a known geometry relative to the radiation delivery device;

determining the location of a machine isocenter relative to the plurality of sensors based upon the position of the reference device;

positioning the body relative to the radiation delivery device with the target isocenter being coincident with the machine isocenter; and
applying radiation from the radiation delivery device to the machine isocenter and the target at the target isocenter.

[c66] 66. The method of claim 65 , further comprising:
implanting a plurality of markers in the body at a selected positions and orientations relative to the target, each marker being excitable by the external excitation source to produce an identifiable marker signal unique to the respective marker;
exciting the implanted markers with the external excitation source to produce the identifiable unique marker signals;
measuring the marker signals from each of the implanted markers with the sensors exterior of the body;
determining a location of the target isocenter in the target within the body based upon the measurements from the sensors of the marker signals.

[c67] 67. The method of claim 65 , further comprising determining the location and orientation of the target in the body relative to the sensors.

[c68] 68. The method of claim 65 wherein the marker generates the marker signal having a signal strength and measuring the marker signals includes measuring the marker strength with each sensor.

[c69] 69. The method of claim 65 , further comprising providing a monitoring system coupled to a computer controller and providing feedback from the computer controller to the monitoring system about the position of the machine isocenter and the target isocenter relative to each other.

[c70] 70. The method of claim 69 wherein the monitoring system includes a visual display portion, and providing feedback includes providing a visual representation on the visual display portion of the positions of the target and machine isocenters relative to each other.

[c71] 71. The method of claim 65 , further comprising implanting at least three markers in the body at selected positions relative to the target, each of the at

least three markers being axially misaligned with each other.

[c72] 72. The method of claim 65 further comprising positioning the body at a selected location generally adjacent to the radiation delivery source, and wherein measuring the marker signal, determining a location of the target isocenter, determining the location of a machine isocenter, and positioning the body relative to the radiation delivery device so the target isocenter being coincident with the machine isocenter are performed in real time prior while the body is positioned at the selected location generally adjacent to the radiation delivery device.

[c73] 73. The method of claim 65 wherein the target is a tumor, and implanting the marker includes implanting the marker in or immediately adjacent to the tumor, and determining the location of the target isocenter includes determining a location of the target isocenter in the tumor.

[c74] 74. The method of claim 65 wherein the sensors are mounted to a movable support table that supports the body generally adjacent to the radiation delivery device, and positioning the body includes moving a portion of the support table relative to the radiation delivery device and to the sensors to align the target isocenter with the machine isocenter.

[c75] 75. The method of claim 65 , further comprising monitoring the position of the target isocenter relative to the machine isocenter in real time during irradiation of the target, and interrupting the irradiation of the target if the target isocenter moves out of alignment with the machine isocenter.

[c76] 76. A method of delivering radiation therapy on a selected target within a body, comprising:
implanting a marker in the body at a selected position relative to the target,
exciting the implanted marker with an excitation source external of the body to produce an identifiable marker signal;
measuring the marker signal from the implanted marker with sensors positioned exterior of the body and at a known geometry relative to each other;
determining a target isocenter in the target within the body based upon the

measurements from the sensors of the marker signal;
determining the location of a machine isocenter of a radiation delivery assembly relative to the plurality of sensors based upon the position of the reference device and relative to the target isocenter;
positioning the body relative to the radiation delivery device so the target isocenter is co-incident with the machine isocenter;
applying radiation from the radiation delivery device to target at the target isocenter and the machine isocenter; and
monitoring in real-time the actual position of the target isocenter relative to the machine isocenter during application of the radiation to the target.

[c77] 77. A radiation treatment planning method for establishing a therapeutic procedure for delivering ionizing radiation to a selected target, comprising:
obtaining imaging data of a selected target within a body;
implanting an excitable marker in the body at a selected location relative to the target;
exciting the implanted marker with the external excitation source to produce the identifiable marker signal from the marker while in the body;
measuring the marker signal from the implanted marker with a plurality of sensors exterior of the body, the sensors being positioned at a known geometry relative to each other;
determining a shape, and spatial orientation of the target within the body from the imaging data;
determining a target isocenter in the target within the body based upon the measurements from the sensors of the marker signal; and
developing a radiation dosage and delivery protocol for irradiating the target at the target isocenter based upon the shape and spatial orientation of the target.

[c78] 78. The method of claim 77, further comprising:
positioning the body with the target and implanted marker therein at a selected position relative to a radiation delivery assembly, the radiation delivery assembly being configured to selectively deliver focused radiation to a target isocenter spaced apart from the radiation delivery assembly;
determining the location of a machine isocenter relative to the plurality of

sensors;

positioning the body relative to the radiation delivery device with the target isocenter being substantially co-incident with the machine isocenter; and

delivering the radiation from the radiation delivery assembly to the machine isocenter and to the target at the target isocenter.

[c79] 79. The method of claim 77, further comprising defining a three-dimensional simulated target model with a selected position and orientation relative to the body based upon the imaging data; and defining an three-dimensional actual target based upon the measurements of the marker signals, providing a feedback device that provides feedback information about the location and orientation of the simulated target model and the actual target model, and moving the body to align orientation of the target and actual models prior to the delivery of the radiation to the target.

[c80] 80. A method of positioning a body relative to a radiation delivery device for delivery of radiation to a target within the body, comprising:

positioning the body on a movable support assembly;

exciting an excitable marker with an excitation source exterior of the body, the marker being implanted within the body at a selected position relative to the target, the excited marker providing an identifiable marker signal;

measuring the marker signal from the implanted marker with a plurality of sensors exterior of the body, the plurality of sensors being positioned at a known geometry relative to each other and relative to the support assembly;

determining a target isocenter in the target within the body based upon the measurements from the sensors of the marker signal;

determining the location of a machine isocenter relative to the plurality of sensors based upon the position of the radiation delivery assembly;

comparing the location of the target isocenter with the location of the machine isocenter; and

moving a portion of the support portion and the body together relative to the machine isocenter to position the target isocenter co-incident with the machine isocenter.

[c81] 81. The method of claim 80, wherein the plurality of sensors are connected to the support assembly, and moving the portion of the support portion includes moving the portion of the support portion and the body together relative to the plurality of sensors.